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SOME INFORMATION ON QUARRY SAFETY

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BY

FRANK E. CASH AND W. H. TOMLINSON

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INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SOME INFORMATION ON QUARRY SAFETY[1]

By Frank E. Cash[2] and W. H. Tomlinson[3]

INTRODUCTION

Published or available data on safety in quarries are few except those pertaining to blasting issued by manufacturers of explosives.

During the past 25 years the quarrying industry (including various types of quarries producing many different materials) has had a markedly improved accident experience. The downward trend has not been phenomenal or has it been uniform from year to year, owing to occasional major disasters; but from the information at hand it appears that improvement during the 25-year period has been definite.

Irregularities are due to such accidents as the slide or cave-in of a quarry wall in North Carolina during 1933, which resulted in the death of seven men; and an explosives accident in a California quarry in 1934, in which nine men were killed. Such accidents have occurred infrequently, but when they do occur the experience curve rises sharply because relatively few men are employed in the industry.

SCOPE

Using accident experience from the principal causes, the operating practices, and natural conditions as they pertain to the quarries in the Southeastern and Central Western States, this report suggests methods, rules, and practices that, if applied to individual quarry operations, would improve the accident experience without excessive cost.

Although the following information and experience are based largely upon quarries in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Ohio, Indiana, Illinois, Missouri, and Tennessee, they are applicable in general to quarrying throughout the United States.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7144."

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CAUSES OF ACCIDENTS

The principal causes of accidents in quarry operation for 1931 to 1935, inclusive, are listed separately in tables 1 and 2 in order of frequency for fatal and nonfatal lost-time accidents:

TABLE 1. - Causes of fatal accidents according to frequency, 1931-35

Causes	Percent
Falls or slides of rock, walls, or overburden	37
Explosives	17
Falls of persons	11
Machinery	10
Haulage	9
Electricity	5
Handling materials	2
Flying objects	2
Other causes	7

TABLE 2. - Causes of nonfatal lost-time accidents according to frequency, 1931-35

Causes	Percent
Handling materials	30
Flying objects	14
Falls or slides of rock, wall, or overburden	10
Haulage	8
Machinery	7
Falls of persons	6
Hand tools	5
Explosives	2
Other causes	18

PREVENTION OF ACCIDENTS

Falls or Slides of Rock, Walls, or Overburden

Falls or Slides of Rock

The character of material handled and method of development largely govern the number of accidents from falls or slides of material. For example, more accidents would result from this cause when quarrying was done in disintegrated material from a steep mountain slope than when it was done in massive close-grained material in level areas.

Regardless of natural conditions, the efforts of employers and employees can reduce the 37 percent fatal and 10 percent nonfatal lost-time accidents caused by falls and slides of material.

Falls of Wall or Face

There are advantages and disadvantages in both the vertical or single-bench and the multiple-bench quarry wall or face; but where natural conditions, preparation equipment, and quality of material desired will allow, the advantages favor the vertical face, certainly up to 125 feet in height.

If the bench method is used, in addition to scaling the face from top to bottom the individual benches should be cleaned to protect drillmen as well as men on the quarry floor.

If the vertical-wall method is used, secondary blasting will be increased, but most of the floor work can be done farther away from the wall or faces. Whether benched or vertical, quarry faces should be inspected and scaled, if necessary, after each wall or face shot and each rain, freeze, or thaw, and under no conditions less often than every 30 days.

Should unsafe material develop on walls or face that cannot be taken down immediately the quarry floor should be barricaded or fenced off near the loose material until it can be taken down. Overhanging material should not be permitted to remain on a face or wall, even if drilling and blasting have to be used to bring it down.

Thorough and proper scaling of walls is hazardous at best because it is necessary that a man or men with safety belts and ropes start at the top of the wall or face and be lowered while scaling, quarrying, and, in some instances, placing explosives in material that might become loose as the scaling progresses downward.

Falls of Overburden

The overburden or loose top material should be stripped or cleaned down thoroughly to the solid-material back for the width of the next shot and at least 10 feet from the wall edge and then sloped to its angle of repose throughout its thickness. In a quarry on a steep mountainside this may be impossible, but baffle boards or screens supported by pipes or rods so spaced and let into the rock that they will support the baffle material not only protect the men on the quarry floor from falling material but also safeguard against falls of persons.

Drilling and Blasting

Explosives as listed under the principal causes of accidents include only those resulting directly from detonation and do not include handling of explosives or machinery in connection with drilling and blasting. The two are so closely allied in quarry operations, however, that they may be considered under one heading.

As the use of explosives constitutes one of the greatest potential hazards in quarry operation the subject will be discussed in detail here. The manufacturers and the Institute of Makers of Explosives have made available instructions and rules for storing, handling, and use of explosives and detonators as well as blasting in quarries, which, if observed, undoubtedly would assist in reducing greatly the frequency and severity of explosives accidents.

Magazines often are built in such places as makes them a menace to an entire community. Improper storage of explosives, detonators, and fuse leads directly to misfires as well as to other classes of explosives accidents.

Magazines should be built of masonry and so constructed that they will disintegrate completely in event of an accidental explosion. Their location should conform to the American Table of Distances, a copy of which is included at the end of this paper. Detonators and explosives should be stored in separate magazines, never in the same building. The detonator magazine should be a safe distance from the main magazine, and detonators and explosives should be kept apart until the moment of charging the holes. Open or electric lights of any kind except permissible portable lamps should not be permitted in or near the magazines. Explosives should be transported from the magazines to the quarry face, preferably by rubber-tired vehicles; when carried by workmen, detonators and explosives should not be taken at the same time.

Much of the broken rock resulting from primary blasting is of such size that considerable secondary blasting is necessary before the material can be loaded. This is especially true at quarries where the size of the crusher does not permit the handling of large boulders and at hand-loading and other quarries where limestone is produced for burning in vertical-type kilns. The blasted material may remain against the face or wall, the broken rock sloping steeply toward the quarry floor; or it may be scattered about the floor for some distance from the face, depending on the nature of the rock and the amount and kind of explosives used. In either case large boulders that must be reduced in size further before being loaded usually remain. Workmen are required to climb onto these boulders to drill and prepare the secondary blasts; as many of the boulders rest at precarious angles on the broken rock the workmen are subjected to the hazard of falling off the boulders or having the latter roll upon them. The situation does not lend itself easily to the use of safety belts or ropes, as usually there is nothing to which these safety devices can be anchored readily. Where conditions permit, this safety equipment should be employed. The hazard also can be abated in some instances by moving the boulders to solid footing with the bucket or boom of the shovel, or by the erection of wooden platforms before the drillers are permitted to work on the boulders.

In vertical-wall blasting it is necessary occasionally to drill the "toe" before the next deep holes are fired. At best this is hazardous work near a high wall on which rock may become loosened and fall. Large rocks that constitute a hazard generally are removed before drilling of the toe is permitted, but in many instances small pieces are not scaled off, and a small piece of rock falling from a great height may easily cause a fatality. This danger can be reduced by the use of long steel, so that the driller is away from the face; but better protection is afforded by an overhead platform, as the face must be approached at least while the hole is charged and the fuse lighted. Men who do this type of work should be required to wear hard hats.

The skill and experience of the man in charge of primary blasting have much to do with the condition of the blasted rock. Proper methods employed by experienced men capable of judging how much explosive is necessary for each shot will go far toward reducing the amount of secondary blasting necessary, thus lowering not only the hazard incident to this operation but also the cost.

Other safe blasting practices often are disregarded. Some of the hazards are: Distributing large quantities of explosives before loading; opening cases with metal tools; dropping heavy charges of dynamite into deep holes; priming drill holes and failing to shunt or short-circuit the detonator leg or connecting wires until ready for connection to trunk lines; shooting too many holes at one time (secondary blasting); and use of open lights and/or smoking near by or while explosives are being handled or used.

If continued, these practices sooner or later lead to accidents. Only enough explosives for one round of holes should be taken from the main magazine at one time, and any that are left over should be returned to the magazine. In primary blasting, where sometimes hundreds of pounds of explosives are used in one shot, preferably only one hole, or possibly a few holes, should be charged and fired at a time, especially if the quarry is situated close to a town. In handling and using large quantities of explosives the danger of accidental ignition is increased; and in detonation, property damage may result, which may subject the company to civil suit. There are two quarries in Indiana where only one hole is fired at a time owing to the proximity of towns and dwellings. In one instance the company was sued for alleged damage to a dwelling as a result of firing numerous shots at one time; in the other, city regulations prohibit the firing of more than one shot at a time.

Cases of explosives should be opened with wooden tools and never with an axe or other metal tool, as is the common practice at many quarries.

Explosives should not be handled for any purpose during an electrical storm. The dynamites should never be dropped into deep holes but should be lowered by a rope. Some manufacturers wrap large cartridges or sticks (5 to 25 pounds or more) with twine, by which they may be lowered with a small hook attached to a rope. Where the sticks are not so prepared, a wooden pin on a rope or some equally safe method should be used.

The detonator leg wires or connecting wires always should be shunted or short-circuited until the moment of connecting the wires to the source of current. The trunk lines also should be short-circuited, and at least one but preferably two or more switches should be placed in the lines at positions remote from the quarry face. The "master" switch should be locked "out" while shots are being connected.

Persons handling or working near explosives should not be permitted to have open lights or smoking materials in their possession. An instance is known in which a quantity of explosives at the bottom of a well-drilled hole was set off by a cigarette. The holes were about 6 inches in diameter and 60 feet in depth and 300 to 400 pounds of explosives usually were fired in each hole. At the time of the ignition about 100 pounds of high explosives had been placed in a hole when the whistle sounded announcing the lunch period. The men doing the work sat down nearby to eat; after finishing, one of the men smoked part of a cigarette, then threw it away. The lighted cigarette fell unnoticed into the open hole containing the explosives, and a short time later the detonation occurred, the shot removing several hundred tons of rock from the quarry face. Fortunately, no one was injured; no one was in the quarry at that point at the time and the men doing the blasting ran a few seconds before the detonation when they observed smoke coming from the hole.

Other precautions that should be followed in connection with primary blasting are: Wet holes should be pumped dry before they are charged unless special care is used in selecting a type of explosive designed for wet work; if the holes are sprung, time should be allowed for cooling before the main explosive charge is inserted; and explosives should be handled and blasting done with the fewest possible number of men exposed to the hazard. The last suggestion applies to secondary blasting also.

Although much smaller quantities of explosives are used in secondary blasting, the hazards are considerably greater, as this work is done oftener and usually while other workmen are in the immediate vicinity. A recent survey of two dozen or more quarries in the Central Western States indicated that more careless practices are followed in secondary blasting than in primary blasting. From 2 or 3 to as many as 300 shots were fired at one time with fuse and cap. In only one instance were shots firec electrically. Obviously, firing a great number of shots at one time increases the hazard of premature blasts and of misfires. Where conditions allow, secondary blasting usually is done at lunch or quitting time; however, in many instances firing is done as needed during the working shift. Primers usually are made up at or near the magazine or at some other point remote from the face, and as many as several dozen at a time are carried to the point where they are to be used. Until charging of the holes is begun, the primers, sometimes with other explosives, are placed on the quarry floor or on the broken rock.

These practices are conducive to accidents and should be stopped. Primers should be made up at the time the explosives are placed in the holes. The blasting caps should be carried in an insulated bag or box, and the caps or primers never should be placed on the ground or on the rock pile. Only a limited number of shots should be fired at one time, the number depending on existing conditions such as the length of fuse and the number of experienced men available for lighting. A good type of igniter (several are now available) should be selected for lighting the fuse, and the fuse used should be long enough to give the men ample time to reach a safe place before the detonations occur. Heavily constructed shelters or buildings should be provided in the quarry where the blasters may seek refuge until shots are detonated.

"Adobe" or mud cap blasting is inefficient and hazardous. In all instances where feasible in secondary blasting holes should be drilled deep enough in the rock to accommodate the explosive charge and allow for enough stemming to confine the charge properly.

For the protection of workmen, visitors, and others danger signs with a code of blasting signals should be posted conspicuously at all entrances, and all employees should be familiar with the code in use. Additional protection should be given the public where highways or railroads are near the quarry property. Flagmen should be stationed on nearby highways and traffic stopped until all shots have been fired. One instance is reported in which a rock from a secondary blast went through the top of an automobile parked on a highway more than a thousand feet from the point where the shot was fired. Workmen should be prevented from returning too soon to the quarry after shots are fired, especially after primary blasting. In several instances men have been overcome by fumes from explosives in open-cut mining.

Extreme care should be exercised in disposing of misfired shots. The unexploded charge should never be removed from the hole. In disposing of these, another hole should be drilled and fired and the unexploded charge then recovered from the broken rock. Two accidents occurred at one quarry from misfires in secondary blasting. In one instance the driller was attempting to start a new hole when the drill bit slipped unnoticed into the previously drilled hole, detonating the misfired charge; in the other, the second hole was drilled at an angle with the first with the obvious purpose of detonating the misfired explosive with the second charge. The second hole progressed until the drill steel struck the explosive, setting it off and killing the driller instantly. His helper, a negro, was so frightened that he ran until he fell dead.

Falls of Persons

Accidents due to falls of persons include falls from buildings, platforms, scaffolds, and ladders and tripping over objects on the ground or floor.

The constant use of safety belts and ropes will go far toward preventing falls from structures above the ground. Such equipment should be tested thoroughly before use, whether daily or intermittent. One quarry visited had had three fatalities in a period of years from falls of persons from elevated structures; in one instance a man fell to the ground from a platform 15 feet high while assisting with the removal of a defective boiler tube; in another, while repairing a dock at a river loading terminal, a workman fell into the river from a platform 30 feet high and was drowned; in the third the fall was similar to that of the other two. In each instance the use of a safety belt undoubtedly would have prevented the accident. Workmen employed at crushers should be required to wear safety belts while feeding the crusher or while attempting to dislodge large boulders, and in no case should they be permitted to enter the crusher pit while the machinery is in motion.

Abandoned portions of quarries should be fenced adequately or screened to prevent men or animals from falling into them accidentally. Where the entrance to the quarry is by ladder or stairway these should be built strongly, provided with suitable railings, and maintained in safe condition at all times. Similar precautions should be taken in connection with stairways and ladders in the mill or plant.

Keeping the quarry floor free of refuse and debris will also assist in preventing accidents from falls of persons. Materials and supplies should be piled neatly and safely to reduce the stumbling hazard.

Where quarries are operated on other than day shift the best possible system of electric flood lighting should be installed, and the workmen should wear portable electric cap lamps.

Machinery

Machinery may be classed as a major cause of accidents, as from 1931 to 1935 (see tables 1 and 2) 10 percent of the fatal and 7 percent of the nonfatal injuries were due to this cause. These accidents resulted from inadequate guarding of gears, pulleys, belts, shafts, and cables, and during repair, greasing, or oiling of moving equipment.

If feasible, all moving machinery with which men may come in contact should be guarded. No one should be permitted or required to repair, adjust, grease, or oil machinery while it is in motion. Men who work with or pass by moving machinery should be required to wear tight-fitting clothing.

Proper and regular inspection of machinery and equipment will prevent many failures and thus prevent many accidents. Cables on shovels and well-drill rigs should be lubricated properly and kept in good repair. Boilers and compressors should be provided with suitable safety valves set to blow off at a safe pressure, and the valves should be tested at regular intervals.

All machinery should be inspected regularly by competent persons and written reports on its condition made and kept on file. Defects revealed by such inspections should be remedied as quickly as possible. If this suggestion is followed rigidly many injuries to persons and failures of equipment will be prevented.

Haulage

Haulage also is a major cause of fatal and nonfatal accidents at quarries. There are many and varied types of haulage, each presenting its own peculiar hazards.

Rock may be loaded into mine cars or automobile trucks by hand or by steam, electric, or gasoline-powered shovels. It may be loaded into trucks or into mine cars that are pushed by hand, or it may be hauled by animals or locomotives to the crusher or to the bottom of an incline and hoisted in cars by rope to the crusher or plant; or it may be loaded into cars or trucks, crushed in the quarry, and delivered to the plant by belt, flight, or bucket conveyors.

Where the material is loaded into automobile trucks the haulage problem, so far as safety is concerned, is simplified. Few workmen are subjected to the haulage hazard, yet fatal and other accidents occur. An instance is on record in which a workman got on a truck to ride from the quarry to the plant. As the truck reached a point on the surface near the crusher the victim jumped from it while it was in motion; and in some manner, never fully determined, he slipped and fell, the rear wheels of the truck passing over his body and causing instant death. A similar accident is known in which a man's leg was crushed so badly that it had to be amputated. Where this type of haulage is employed men should be prohibited from getting on or off trucks while they are in motion. Safe procedure also requires that men be prohibited from walking on roads on which the trucks operate.

Where slopes or inclines are used there is always danger that runaway cars or trips will come back into the quarry. Safety switches or other devices should be installed to derail runaway trips on all inclined planes, and a clear path for a quick getaway to safety should be maintained so that the hooker-on (man who hooks the rope to the cars) can seek refuge if the runaway crosses the derail device. Ropes used on incline planes should be large enough for the work, with a large factor of safety, and should be fastened securely to the clevis or chain by which they are connected to the cars. They should be examined daily for defects and should be discarded when inspection indicates that they probably are unsafe.

Haulage tracks should be installed and ballasted properly, and all switches should be equipped with throws. Owing to the undulating quarry floor the tracks quite often are elevated and blocked with large rocks or refuse, wood, or other materials and are not filled in. Inasmuch as haulage employees, repairmen, and sometimes others must walk these tracks, they should be filled in properly, at least to the ties.

Cars used at quarries usually are of the side-dump type. Occasionally they are overloaded and often unevenly loaded, especially in mechanically operated quarries where, owing to the haste or indifference of the shovel operator, large boulders are sometimes placed at precarious angles on top of the cars, causing them to tip or dump while in transit. When it is necessary for men to ride from the face to the crusher or incline they should do so on or in the locomotives, never on the cars. While being loaded, cars sometimes are dumped inadvertently by the shovel dipper or large boulders; therefore, haulage crews, ground men, and others should not remain near the cars during this cycle of the operation. Cars moved by hand should be pushed rather than pulled; when they are not connected to a locomotive they should be blocked securely while being loaded. Where hoists are used they should be situated so that the operator has a clear view of the trips at all times.

Adequate clearance should be provided between the railroad cars and mill or plant supports. Where the cars are controlled by hand to and from the loading point the car-droppers should wear safety belts.

Electricity

Electricity is a minimum cause of accidents at quarries; however, when an accident is caused by electricity it usually is serious. Electrical accidents can be prevented by following a few simple rules.

All conductors should be carried on insulators supported on poles or in conduit or special armored cables. Stationary transformers should be placed on poles high above the ground or at least properly fenced when at or near the ground level. The frames of all stationary electrical apparatus should be grounded efficiently; this precaution should be taken with armored cables also. High-tension cables, preferably all power-carrying lines, should be handled with lineman's gloves or an insulated stick with a suitable hook at one end. Closed switches should be provided in all lines and provision made for locking them open when it is necessary to work on or make repairs to the lines.

Where locomotives are operated from a trolley wire the tracks should be bonded and cross-bonded efficiently and the trolley wires held taut by proper supports at least 8 feet above the ground. The trolley system should be protected by switches placed in the lines at intervals to provide several points at which the power can be cut off in emergencies. "Third-rail" systems occasionally are employed at quarries, and where these prevail precautions should be taken to keep persons from coming in contact with the third rail; moreover, explosives and all shot-firing wires and lines used in electrical blasting should be kept away from the car tracks.

Suitable warning and caution signs should be posted conspicuously at or near all stationary electrical equipment and lines; in addition, instructions on the resuscitation of persons suffering from electric shock should be posted at strategic points, and all persons working in connection with electrical equipment should be familiar with and know how to follow these instructions.

Handling Materials

Handling materials enters into virtually every phase of the operation at quarries, and, although responsible for only 2 percent of the fatalities, it is the most frequent cause of lost-time nonfatal injuries, accounting for 30 percent of all such accidents.

This type of accident can be reduced through education and training of employees in the proper method of lifting and carrying. The use of safety clothing, including hard-toe shoes, hard hats, gloves, and tight-fitting clothing, will assist greatly in reducing accidents from this cause.

Flying Objects

Injuries from flying objects result largely from blasting, crushing by loading machines or crushers, breaking rock by hand, collaring holes, rock falling from cars or platform, and others. Flying objects are responsible for only 2 percent of the fatalities, but, like the hazard from handling materials, this cause is responsible for a great number of nonfatal injuries.

Preventive measures, as they pertain to blasting, have been discussed in this paper under the heading Drilling and Blasting. Ground men and others should be instructed to remain at a safe distance while loading machines are operating. Heavy screens or other equally safe protection should be provided at roller-type crushers, which usually operate at high speed and sometimes throw small particles of rock from the pit at tremendous velocity. Caution signs should be posted calling attention to the danger of flying rock.

Much hand-breaking of rock is done in quarries at lime plants, where the limestone must be within certain size limits for use in vertical kilns, and also at quarries where riprap is produced. This operation has caused many serious eye injuries. These accidents can be reduced easily and possibly eliminated by the compulsory use of proper goggles. Foremen should be required to see that all workmen take this precaution while breaking rock. Workmen who fail or refuse to take this precaution should be penalized. At one quarry visited, about two dozen men were observed breaking riprap. All of them were provided with goggles, but only about half were wearing them. Among those not wearing goggles was an employee who had lost an eye previously while breaking rock. When the foreman approached the place where these men were working several put their goggles on, but the man with only one eye, with several others, continued to work without theirs. Obviously, little effort had been made to inform these workmen regarding the hazards incident to their occupation and to enforce the discipline necessary to reduce accidents.

Corrective goggle lenses should be provided for employees who need them. This is being done by some quarrying companies.

Dust

No subject before the public today is more interesting to those engaged in promoting health and safety than the dust hazard. Industry in general has just begun to devote the attention to this subject that its importance warrants. The quarrying industry as a whole apparently fails to recognize its importance, as indicated by the absence of precautions to prevent workmen from breathing large quantities of fine dust. In fact, personal contact with many operating officials revealed their belief that the dust at limestone quarries constitutes no hazard, and some have even argued that the dust has a beneficial effect on man. In the light of present knowledge of the disastrous and lasting effects of dust on human beings nothing could be farther from the truth. Experts who have devoted years to the study of dust diseases are preponderantly of the opinion that any and all dusts taken into the human system are harmful.

Workmen in rock quarries and plants are subjected daily to breathing large quantities of fine dust, especially in mills where cement, lime, or rock wool are manufactured and where sandstone is ground fine for glass making or other purposes. Progressive operators will not delay in providing protection against dust diseases until compensation costs make such action imperative, but will take immediate steps to combat the hazard.

Dust is best controlled at its source. There are three general methods of protection against breathing dusts: (1) Dust-collecting equipment, (2) use of water, and (3) use of respirators. One, a combination of two, or the three general methods will go far toward reducing the hazard. The first method is applicable to and should be used in all closed buildings in which much fine dust is produced in crushing, screening, and conveying the broken rock. The second applies principally to the use of water during drilling, especially when collaring and when blowing out the holes. Suitable respirators should be worn by men at any occupation where dust exists in the atmosphere in noticeable quantities. Men should not be permitted to return to the quarry after blasting until the dust has settled; where the dust is very fine and the clouds are heavy the broken rock should be sprayed before the men are permitted to resume work.

Miscellaneous

Causes not listed previously are responsible for 7 percent of the fatal and 18 percent of the lost-time injuries. Some of these are stepping on nails, boiler and air-lock explosions, hand tools, and burns.

Accidents due to stepping on nails can be prevented by good housekeeping methods, including the education and training of employees. Workmen should be taught to remove or bend over all nails protruding from equipment or refuse. This type of accident results from downright carelessness and can be eliminated easily by stressing the hazard and insisting that the cause be removed.

Explosions have been discussed under the heading Machinery.

Foremen should be required to see that all hand tools are kept in safe condition at all times, and that any found to be defective should be repaired before they are used again. Daily inspection of tools will reveal to the foreman when any are unsafe for use.

Good housekeeping methods and special instruction of all employees also will go far toward preventing injuries from burns. Open lights and fires should be kept under proper control and employees instructed regarding the hazards incident to their use. Steam lines, boilers, and other heated objects should be guarded properly or protected against contact by persons, and all electrical equipment likely to cause burns should be insulated.

SUPERVISION AND DISCIPLINE

Adequate supervision and maintenance of rigid discipline are of greatest importance in the economic as well as the safe operation of any quarry. When permitted to follow their own inclinations, employees will take chances and follow unsafe practices in their work. Many of these preculiarities can be corrected by proper education and training of all employees; those who are incapable of responding to such training should be placed in less hazardous occupations, and those who refuse to benefit thereby should be penalized. All officials should be held strictly responsible for the safe and efficient operation of their respective departments.

ORGANIZATION

Supervision and discipline can be maintained only through proper organization. Efficient and safe conduct of all phases of the work is assured by following a well-planned schedule indicating the manner in which each operation is to be performed. Employees should be made to feel they are part of the program, and all hazards incident to their jobs should be pointed out. The management should insist that all work be done in a safe manner, and where necessary the plan should be changed to achieve this. Written rules and regulations should be provided and all employees made familiar with the requirements.

In addition to the training given while at work, all employees should receive additional instruction through the medium of regular safety meetings. Where these meetings are held on company time, as is now being done at many quarries, the attendance of the employees can be made compulsory; otherwise, the programs can be made so interesting that the workmen will attend of their own volition. Many quarries that now enjoy enviable safety records hold regular weekly or monthly meetings that are attended by at least a committee of workmen from each department. The men are encouraged to look for and report hazards observed in connection with their work, and the management usually makes every effort to remove these hazards as soon as practicable after they are reported. In this manner the employees are made aware of the sincerity of the management in its desire to operate without accidents.

The organized program for safety at all quarries should include provisions for training in first aid to the injured. Preferably, all employees as well as officials should be trained properly, and all persons should be retrained at approximately yearly intervals. First-aid materials and supplies should be kept on hand ready for use in emergencies. Many lives have been saved and serious aftereffects avoided by prompt and efficient treatment of nonfatal injuries at the time of the accident. First-aid training, especially 100-percent training with all persons at a quarry taking the work, is an excellent foundation upon which to build an accident-prevention program.

SUGGESTIONS FOR QUARRY SAFETY

Falls and Slides of Material

Overburden

1. The overburden should be cleaned thoroughly at least 10 feet back from the face and then sloped to its angle of repose over its entire thickness.

2. If the quarry is in a steep mountainside baffle boards or screens should be erected around the top edge of the wall or face.

Wall or Face

3. Where material and preparation equipment permit the walls should be vertical.

4. If the bench method is used benches should be at least 10 feet wide, kept free of loose material, and equipped with a toe board and hand railing of cable or rope on the open side.

5. Walls and benches should be inspected and scaled if necessary after each wall or bench shot, after each rain, thaw, or freeze, and at least once every 30 days.

6. Safety ropes and belts should be used by all men who scale walls and benches.

7. Safety ropes and belts should be tested before each wearing.

8. Men who scale quarry walls or benches or work near the walls or around shovels should wear protective hats or caps.

Explosives and Blasting

9. Explosives magazines should be of masonry and constructed so that they will disintegrate completely in case of accidental explosion. The locating of magazines should conform to the American Table of Distances.

10. Detonators and explosives should be stored in separate magazines.

11. Open lights or electric lights of any kind, except permissible portable type, should not be permitted in or near magazines.

12. Explosives should be transported between the magazines and the quarry, preferably by rubber-tired vehicles; if carried by persons, detonators and explosives should never be taken at the same time.

13. Where there is serious danger of men falling off large boulders or of the boulders rolling upon them, safety belts should be used when practicable; where this is not feasible platforms should be erected from which the drilling and blasting can be done.

14. When necessary to drill and blast the "toe" before deep holes are begun in vertical-wall blasting the drillers should be protected by an overhead platform, or long steel should be used to enable them to do this work at a safe distance from the face.

15. Explosives should not be distributed in large quantities before loading; the best practice is to deliver only enough for one hole at a time.

16. Explosives should not be handled for any purpose during an electrical storm.

17. Where quarries are situated near dwellings or towns preferably only one hole should be fired at a time in primary blasting.

18. Wood tools should be used in opening explosives cases.

19. Heavy sticks of explosives should be lowered, never dropped, into deep holes.

20. Detonator leg wires and connecting wires should be short-circuited until it is necessary to make connections to the source of power.

21. Shot-firing circuits should be protected, preferably by two or more switches, and the master switch should be locked "out" while not in use.

22. Men handling explosives or working nearby should be prohibited from having smoker's articles in their possession.

23. Wet holes should be pumped dry before they are charged unless explosives especially designed for wet work are used.

24. Where holes are sprung enough time should be allowed for cooling before they are charged.

25. Explosives should be handled and blasting done with the fewest possible number of men exposed to the hazard.

26. Detonators should be carried in insulated bags or boxes.

27. Primers should be made up at the time they are charged into the holes.

28. The number of secondary shots fired at one time should be limited unless the shots are ignited electrically.

29. A positive type of igniter should be used for lighting fuse.

30. Heavily fortified structures should be provided in the quarry, in which the shot firers may seek refuge while blasting.

31. Adobe or mud-cap blasting should be reduced to a minimum; holes should be drilled deep enough to accommodate the explosive and allow for enough stemming to confine the charge properly.

32. Danger signs with a code of blasting signals should be posted conspicuously at all entrances to the quarry and all workmen made familiar with the signals in use.

33. Additional protection should be given to the public during blasting by the use of flagmen on highways, and shots should not be fired while trains are passing quarries.

34. Men should be prohibited from returning to the quarry too soon after blasting.

35. Extreme care should be exercised in disposing of misfired shots; a new hole should be drilled and fired and the unexploded charge recovered before further work is done. In no case should the misfired charge be removed from the hole.

Falls of Persons

36. Safety belts and ropes should be used by men working on structures high above the ground.

37. This equipment should be used also by men feeding the crushers, and no one should be permitted to enter the crusher pit while the machinery is in motion.

38. All quarries should be fenced so that men or animals cannot fall into them.

39. Walkways should be kept free of loose materials and all ladders and stairways provided with proper railing.

40. The quarry floor should be kept free of refuse and debris.

41. Materials and supplies should be piled neatly and safely in the quarry.

42. Where work is done at night a good system of flood-lighting should be used and workmen should be provided with portable electric lamps.

Machinery

43. All moving machinery with which men may come in contact should be guarded adequately.

44. No one should be permitted or required to repair, adjust, or lubricate machinery in motion.

45. Boilers and air compressors should be equipped with proper-type safety valves set to blow off at safe pressures, and the valves should be tested at regular intervals.

46. All machinery should be inspected regularly, and written reports should be made and kept on file indicating the condition of the equipment at all times.

Haulage

47. Men should be prohibited from getting on or off moving automobile trucks.

48. A safety switch or equally effective derail device should be installed on all incline planes and slopes, and an unobstructed path should be maintained for retreat to safety by the "hooker-on" in case of runaway trips.

49. Ropes used on slopes and planes should be of adequate size, with a large factor of safety, and should be fastened securely to the clevis or chain by which they are attached to the cars.

50. Tracks should be laid and ballasted properly and all switches should be equipped with throws.

51. Unauthorized persons should not be permitted to ride on the cars.

52. Haulage employees and ground crews should be instructed to exercise precaution to prevent accidents to themselves from dumping of cars by the shovel while loading or while in transit.

53. Men should be required to remain at a safe distance from the shovel bucket and cars while they are being loaded.

54. When moved by hand, cars should be pushed, not pulled.

55. Cars not coupled to locomotives should be blocked securely while being loaded.

56. Hoists should be situated so that the operator has a full view of the trips at all times.

57. Clearance should be adequate between railroad cars and the mill or plant building supports.

58. Car-droppers should wear safety belts.

Electricity

59. Transformers should be placed on poles high above the ground or fenced securely.

60. Frames of stationary electrical apparatus should be grounded effectively.

61. Power cables should be handled with linemen's gloves or with an insulated stick.

62. Closed-type switches should be inserted in all power lines except trolley circuits.

63. Power switches should be locked "out" when repairs are being made to the lines or other equipment.

64. Power switches should be operated from an insulated platform.

65. Where trolley locomotives are used the car tracks should be bonded and cross-bonded efficiently.

66. Trolley wires should be kept taut at all times and maintained at least 8 feet above the rails.

67. Trolley circuits should be protected with switches at regular intervals.

68. When "third-rail" trolley systems are used, precautions should be taken to keep persons from contacting the live rail, and explosives and shot-firing wires should be kept away from the car tracks.

69. Suitable warning signs should be posted at all stationary electrical apparatus and lines.

70. Instructions for resuscitation of persons suffering from electric shock also should be posted.

71. All persons working in connection with electrical equipment should be familiar with and know how to carry out these instructions.

Handling Materials

72. The proper equipment should be provided for safe handling of materials.

73. Men should be trained in the proper method of lifting and carrying heavy objects.

74. Men should not be required or permitted to lift or carry objects obviously too heavy for them.

75. All workmen should be required to wear safety shoes and hard hats, and for some work they should wear gloves.

Flying Objects

76. Heavy screens or other safe protection should be provided at roller-type crushers. Caution signs should be posted warning against the danger of flying rock.

77. Shovel operators should be protected by shatterproof glass or wire screen placed in their line of vision.

78. The following men should wear goggles:

(a) Shovel ground men and crusher men.
(b) Workmen who break or chip rock by hand and all others working nearby while hammers are being used.
(c) Truck drivers and locomotive crews, while moving, loading, or unloading.

79. Corrective goggle lenses should be given to all workmen who need them.

Dust

80. Dust-collecting systems should be installed in all closed buildings where rock is crushed, conveyed, and screened.

81. In drilling with air hammers, water or dust-collecting systems should be used.

82. Workmen should be required to wear respirators wherever dust exists in the atmosphere in noticeable quantities.

Miscellaneous

83. Employees should be instructed to remove all nails and sharp objects protruding from equipment or refuse.

84. Foremen should be required to inspect all hand tools daily and prohibit the use of any found to be unsafe.

85. Open lights, fires, steam lines, boilers, and other heated objects should be protected against contact by persons; electrical equipment likely to cause burns should be insulated properly.

Supervision and Discipline

86. Adequate supervision and rigid discipline should be instituted and maintained.

87. Supervising officials should be held strictly accountable for accidents to employees under their charge.

Organization

88. Safety and economy can be realized only through well-planned organization.

89. Rules and regulations covering each operation should be promulgated.

90. All employees should be trained thoroughly in their respective occupations.

91. Regular safety meetings should be held and attended by all employees.

92. All employees should be trained in methods of first-aid-to-the-injured.

93. First-aid materials and supplies should be kept on hand for emergency use.

94. All accidents should be investigated, suitable records kept, and the statistics used as a basis for comparison. Without such records no yardstick is available for measuring advance or decline, and stimulus to increased efforts is absent.

CONCLUSION

Though many different types of materials are extracted in quarry operations, the procedure does not vary over the entire industry so widely as to preclude a definite method where safety as well as efficiency is affected.

Companies that are following organized procedure covering both accident-prevention and production have realized a steadily downward trend in accidents with consequent enviable safety records, which, in turn, reflect directly upon economy of operation. Many quarries are now operating for long periods without lost-time accidents; it is believed that the records of all plants where accidents occur regularly can be improved considerably. It is recommended that operators of all quarries give serious consideration to the foregoing suggestions for safe operation and adopt those that apply to their particular conditions.

AMERICAN TABLE OF DISTANCES
1919 REVISION

Blasting and Electric blasting caps		Other explosives		Inhabited buildings barricaded[1] (feet)	Public railway barricaded[1] (feet)	Public highway barricaded[1] (feet)
Number over-	Number not over-	Pounds over-	Pounds not over-			
1,000	5,000	---	---	15	10	5
5,000	10,000	---	---	30	20	10
10,000	20,000	---	---	60	35	18
20,000	25,000	---	50	73	45	23
25,000	50,000	50	100	120	70	35
50,000	100,000	100	200	180	110	55
100,000	150,000	200	300	260	155	75
150,000	200,000	300	400	320	190	95
200,000	250,000	400	500	360	215	110
250,000	300,000	500	600	400	240	120
300,000	350,000	600	700	430	260	130
350,000	400,000	700	800	460	275	140
400,000	450,000	800	900	490	295	150
450,000	500,000	900	1,000	510	305	155
500,000	750,000	1,000	1,500	530	320	160
750,000	1,000,000	1,500	2,000	600	360	180
1,000,000	1,500,000	2,000	3,000	650	390	195
1,500,000	2,000,000	3,000	4,000	710	425	210
2,000,000	2,500,000	4,000	5,000	750	450	225
2,500,000	3,000,000	5,000	6,000	780	470	235
3,000,000	3,500,000	6,000	7,000	805	485	245
3,500,000	4,000,000	7,000	8,000	830	500	250
4,000,000	4,500,000	8,000	9,000	850	510	255
4,500,000	5,000,000	9,000	10,000	870	520	260
5,000,000	7,500,000	10,000	15,000	890	535	265
7,500,000	10,000,000	15,000	20,000	975	585	290
10,000,000	12,500,000	20,000	25,000	1,055	635	315
12,500,000	15,000,000	25,000	30,000	1,130	680	340
15,000,000	17,500,000	30,000	35,000	1,205	725	360
17,500,000	20,000,000	35,000	40,000	1,275	765	380

[1] Barricaded, as here used, signifies that the building containing explosives is screened from other buildings, railways, or from highways by either natural or artificial barriers. Where such barriers do not exist, distances should be doubled.

AMERICAN TABLE OF DISTANCES
1919 REVISION

Blasting and Electric blasting caps		Other explosives		Inhabited buildings barricaded[1] (feet)	Public railway barricaded[1] (feet)	Public highway barricaded[1] (feet)
Number over-	Number not over-	Pounds over-	Pounds not over-			
		40,000	45,000	1,340	805	400
		45,000	50,000	1,400	840	420
		50,000	55,000	1,460	875	440
		55,000	60,000	1,515	910	455
		60,000	65,000	1,565	940	470
		65,000	70,000	1,610	970	485
		70,000	75,000	1,655	995	500
		75,000	80,000	1,695	1,020	510
		80,000	85,000	1,730	1,040	520
		85,000	90,000	1,760	1,060	530
		90,000	95,000	1,790	1,075	540
		95,000	100,000	1,815	1,090	545
		100,000	125,000	1,835	1,100	550
		125,000	150,000	1,900	1,140	570
		150,000	175,000	1,965	1,180	590
		175,000	200,000	2,030	1,220	610
		200,000	225,000	2,095	1,260	630
		225,000	250,000	2,155	1,295	650
		250,000	275,000	2,215	1,330	670
		275,000	300,000	2,275	1,365	690
		300,000	325,000	2,335	1,400	705
		325,000	350,000	2,390	1,435	720
		350,000	375,000	2,445	1,470	735
		375,000	400,000	2,500	1,500	750
		400,000	425,000	2,555	1,530	765
		425,000	450,000	2,605	1,560	780
		450,000	475,000	2,655	1,590	795
		475,000	500,000	2,705	1,620	810

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